

APPLICATION FOR UNITED STATES LETTERS PATENT

FOR

**INDIRECT MONITORING OF SEMICONDUCTOR
LIGHT SOURCE WITHIN A PHOTONIC PACKAGE**

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INDIRECT MONITORING OF SEMICONDUCTOR LIGHT SOURCE WITHIN A PHOTONIC PACKAGE

FIELD OF INVENTION

5 The invention relates to the field of photonic packaging. More specifically, the invention relates to monitoring of a semiconductor light source within the photonic packages.

BACKGROUND OF THE INVENTION

10 With advances in integrated circuit, microprocessor, networking and communication technologies, an increasing number of devices, in particular, digital computing devices, are being networked together. Such devices are often first coupled to a local area network, such as an Ethernet-based office/home network. In turn, the local area networks are interconnected together through wide area
15 networks, such as Synchronous Optical Networks (SONET), Asynchronous Transfer Mode (ATM) networks, Frame Relays, and the like. Of particular importance is the TCP/IP based global inter-network, the Internet. The rapid growth of the Internet has fueled a convergence of data communication (datacom) and telecommunication (telecom) protocols and requirements. It is increasingly important that data traffic be
20 carried efficiently across local, regional and wide area networks.

 The widespread deployment of high-speed networking and communications equipment has produced a large demand for various types of networking and

communications components and subsystems. Included among these, are modules, which are often referred to as optical transponders.

Optical transponders typically include components for both electrical signal processing, and components for transmission and reception of optical signals.

- 5 Conventional optical transponders typically receive data representing electrical signals in parallel, serialize the data represented, encode the serialized data onto a light-based signal, and couple that optical signal to an outbound optical fiber. Similarly, conventional optical transponders, typically receive a light-based signal having data serially encoded thereon, recover the data in an electrical form, de-
10 serialize the data and provide them in a parallel format to a plurality of output terminals.

- Conventional optical transponders typically include a case, or housing, within which the electrical and optical components are enclosed. Such a housing provides physical protection for the components therein, and also provides thermal
15 conductivity so that heat may be dissipated from the components disposed within the case. The number of components may be numerous. However, a requirement of the housing is that the housing be of a small form factor. Accordingly, in order to have the components within a housing of a small form factor, placement of the components is an important aspect of the optical transponder.

- 20 Placement of the components may be determined by one component's operation relative to another's. For example, as described above, a component, such as a semiconductor light source, that operates to provide light-based signals is

placed in such a manner as to be optically coupled to another component, such as an optical fiber, that operates to optically transmit light-based signals.

Integrity of the light-based signals and stability of the semiconductor may be based upon power output of the semiconductor light source. Accordingly, an important component of an optical transponder is semiconductor light source monitoring device, such as a photodetector, that can monitor the power output of the semiconductor light source. Due to design of a common semiconductor light source used in optical transponders, the semiconductor light source can provide light in more than one path, e.g., two light paths, simultaneously. One light path, commonly known as light source facet, is directed to the optical fiber. Another light path, commonly referred to as back facet, may be directed to a light receiving area of the photodetector. The photodetector receives the light via the light receiving area, or window, and the light is converted to electrical signals, which are sent to another component to be processed to determine the integrity of the light-based signals and stability of the semiconductor light source (i.e., optical power, temperature, and the like). This monitoring is commonly referred to as back-facet monitoring (BFM). The light source facet and the back facet are on opposite sides of each other. Accordingly, placement of the photodetector is opposite side of the semiconductor light source coupled to the optical fiber.

As the form factor of the housing of the optical transponder continues to become smaller, placement of the photodetector in the light path opposite the optical fiber side of the semiconductor light source becomes increasingly difficult due to various components included in the housing.

BRIEF DESCRIPTION OF DRAWINGS

The invention is illustrated by way of example and not by way of limitation in the figures of the accompanying drawings, in which the like references indicate similar elements and in which:

5 **FIGURE 1** illustrates an example photonic package, more specifically, an optical transponder, with which an embodiment of the invention may be practiced;

FIGURE 2 illustrates indirect monitoring of a semiconductor light source by a photodetector within a photonic package, in accordance with one embodiment of the invention; and

10 **FIGURES 3A-3B** illustrate indirect monitoring of a semiconductor light source by a photodetector within a photonic package, in accordance with an alternate embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The invention facilitates indirect monitoring of a semiconductor light source by a photodetector within a photonic package. In the following description, various aspects of the invention will be described. However, one skilled in the relevant art will recognize that the invention may be practiced without one or more of the specific details, or with other methods, materials, components, etc. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of various embodiments of the invention. Similarly, for purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of the invention. Nevertheless, the invention may be practiced without the specific details. In other instances, well-known features are omitted or simplified in order not to obscure the invention. Furthermore, it is understood that the various embodiments shown in the figures are illustrative representations and are not necessarily drawn to scale.

Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure, material, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. Thus, the appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment or invention. Furthermore, the particular features, structures, materials, or characteristics may be combined in any suitable manner in one or more embodiments.

For the purposes of describing the invention, lightwaves will be illustrated as straight lines. However, one skilled in the relevant art will appreciate that lightwaves may behave as waves or particles. Additionally, certain established principles of physics will not be described in detail, in particular, derivations of equations such as those describing the behavior of semiconductors and the like will not be described in detail. However, relevant equations will be described but not derived.

Accordingly, the concept of data carried by lightwaves will not be described in detail. However, for the purposes of the invention, the concept of utilizing different wavelengths of lightwaves to carry different data will be referred to in describing the invention.

FIGURE 1 illustrates an example photonic package, more specifically, an optical transponder with which an embodiment of the invention may be practiced. Illustrated in **FIG. 1** is a perspective view of a portion of the optical transponder, in particular, a housing **100** of the optical transponder with its cover (shown as ref. **310** in **FIG. 3**) removed exposing various components of the optical transponder. In the interior of the housing **100** is illustrated a light source **101** having a rectangular shape. The light source may be a semiconductor light source, such as, but not limited to, a Gallium arsenide (GaAs) laser. On one side of the semiconductor light source **101**, are optical components, such as but not limited to, focusing lenses **104** for focusing a first light output of the semiconductor light source **101** to be provided to an optical fiber (not shown). For ease of understanding, this side will be referred to the front side of the semiconductor light source **101**. On the opposite side (or the back side) of the semiconductor light source **101** is a substrate **102** having various

components mounted on it. The elevation of the substrate **102** is higher than the semiconductor light source **101**. More importantly, substrate **102** is disposed right next to semiconductor light source **101**, thereby resulting in one of its side surface **105** serving as a "back wall" for the semiconductor light source **101**. Further, in accordance with the present invention, side surface or back wall **105** is angularly disposed, relative to the back light facet of semiconductor light source **101**.

For the illustrated embodiment, substrate **102**, when viewed from the top, is substantially trapezoidal in shape, with side surface **105** being the surface disposed on an angular side of the trapezoidal substrate **102**. In alternate embodiments, substrates of other shapes may be employed, including but not limited to triangle, rectangle, and polygon, so long as the disposition orientation of the substrate results in its surface of the side next to semiconductor light source **101** being angularly disposed relative to the back light facet of semiconductor light source **101**. Further, back wall **105** may be provided by other non-substrate component, to be described in further detail below.

Continuing to refer to **FIG. 1**, as alluded to earlier, the semiconductor light source **101** is positioned in such a manner as to have a light source facet (front facet) **102** providing a first output (shown as ref. **202** in **FIG. 2**). Opposite the front facet **102**, the semiconductor light source **101** has a back facet **103** facing towards the back wall **105** providing a second output. As illustrated in **FIG. 1**, space within a housing of a photonic package, such as the illustrated optical transponder, can be very limited due to various components and form factor requirements (i.e., numerous components while small form factor).

In order to describe the invention, references will be made to an exemplary area **110 & 350** (an area around the semiconductor light source).

FIGURE 2 illustrates indirect monitoring of a semiconductor light source by a photodetector within a photonic package, in accordance with one embodiment of the invention. Illustrated in **FIG. 2** is a view of the exemplary area **110** (shown in **FIG. 1**). In **FIG. 2**, semiconductor light source **101** provides a first output **201** from the front facet **102**. As alluded to earlier, in **FIG. 2**, the first output **201** may be directed towards focusing lenses **104** for focusing light to be provided to the optical fiber (not shown). Also illustrated in **FIG. 2** is second output **202** from the back facet **103**.

Semiconductor light source **101** may be a semiconductor laser, in which case, the first and second outputs **201-202** may each be coherent laser light. Accordingly, illustrated in **FIG. 2**, when the second output **202** is incident on the surface or back wall **105** angularly disposed relative to the second output **202**, the second output **202** may be reflected by the surface or back wall **105**. The resultant illustrated as reflected light **210**. In **Fig. 2**, the outputs **201-202** and the reflected light **210** are illustrated visually as different lights. However, it should be appreciated by those skilled in the relevant art, that the visual difference is only for ease of understanding the invention, and does not represent differences in the light.

Illustrated also in **FIG. 2** is a photodetector **205** of the photonic package positioned to receive the reflected light from surface or back wall **105**, in accordance with one embodiment of the invention. The photodetector **205** may be a photodiode, such as, but not limited to, p-layer, intrinsic layer, and n-layer (p-i-n) junction photodiode, an Schottky photodiode, or an avalanche photodetector. As illustrated

in **FIG. 2**, the photodetector **205** is positioned in a coordinated manner relative to the angular surface or wall **105**, such that it may receive reflected light **210** from the interior surface **105**. The reflected light **210** may be received by the photodetector **205** through a window (shown as ref. **331** in **FIG. 3**) of the photodetector **205**.

- 5 Accordingly, as illustrated in **FIG. 2**, the window **331** of the photodetector faces angular surface or back wall **105**. Additionally, illustrated in **FIG. 2**, the photodetector **205** is disposed on a tracing **207** to facilitate transmission of electrical signals output by the photodetector **205** responsive to the received reflected light to a processor (not shown). The photodetector **205** is adapted to produce an electrical
- 10 signal responsive to the reflected light based at least on properties of the photodetector **205** such as, but not limited to, spectral responsivity, external quantum efficiency, noise, response time, dark current, and junction capacitance.

For example, the photodetector **205** may be a p-i-n junction photodiode, where spectral responsivity may be expressed as

15
$$R = \frac{I}{L}$$
 Equation 1

In **Equation 1**, I is amperes of current generated by the photodetector **205**, and L is power of incident light, the reflected light **210**, measured in watts. R is responsivity in units of amperes per watt. Furthermore, external quantum efficiency of a photodiode is its capability to convert light energy to electrical energy (i.e., electrical

20 signals), and can be expressed as a relation to responsivity as

$$EQE(\lambda) = \frac{I(\lambda)hc}{\Phi(\lambda)ne\lambda}, \quad \text{Equation 2}$$

where $EQE(\lambda)$ is external quantum efficiency as function of wavelength, I is photocurrent (output current – dark output current) as function wavelength, h is Planck's constant, c is velocity of light, Φ is input radiant flux (power), n is index of refraction of air, e is elementary charge, and λ is wavelength of light in units of nanometers. Accordingly, the **Equation 1** and **Equation 2** can be utilized to form the relationship

$$EQE(\lambda) = 1239 \frac{R}{\lambda}, \quad \text{Equation 3}$$

where R and λ , as defined earlier, are responsivity in units of amperes per watt and wavelength of light in units of nanometers, respectively.

The electrical signals may be provided to the processor wherein the electrical signals may be compared to characterization data. The characterization data may relate electrical signals from the photodetector **205** produced by reflected **210** light received by the photodetector **205** of the first output **201** of the light source **101**. For example, referring to **FIG. 2**, characterization data may be produced by having several data points corresponding to power of light of the first output **201** from the front facet **102** as compared to power of light of the reflected light **210**. The processor has at least access to the characterization data to facilitating calibration of the reflected light **210** by the photodetector **205**. Affects, such as, but not limited to, temperature may also be accounted for during the calibration process. Accordingly, as the processor receives the electrical signals from the photodetector **205**, the processor may facilitate adjustments to bias voltages of the photodetector **205** to ensure proper monitoring of the semiconductor light source **101**.

As a result, a photodetector can be adapted to receive light reflected from a surface of a component disposed at the back of the semiconductor light source, housed inside a densely populated housing of an optical transponder, thereby advantageously monitoring a semiconductor light source from locations other than those that are directly behind the semiconductor light source (i.e., the photodetector is not required to be in direct path of the back output of the semiconductor light source).

FIGURES 3A-3B illustrate indirect monitoring of a semiconductor light source by a photodetector of a photonic package, in accordance with an alternate embodiment of the invention. Illustrated in **FIG. 3A** is a side view **300** of the housing **100** (shown in **FIG. 1**) with its cover **310** covering the various components within the housing **100**. Commonly, the cover **310**, walls (not shown) and floor (not shown) aids in forming a hermetic seal to prevent outside influences, such as, particulate, humidity, etc. In the alternate embodiment illustrated in **FIG. 3A**, a reflective mirror surface **301** is provided to deflect the second output **202** from the back facet **103** of the semiconductor light source **101** to an interior surface of the cover **303**. Accordingly, the deflected second output **202** incidences on the interior surface of the cover **303**, reflecting off the surface, and forming cover reflected light **305**.

In one embodiment, the interior surface of the cover **303** may have a coating to help facilitate cover reflected light **305**, such as, but not limited to, paint having a pigment of titanium dioxide (i.e., white paint).

In one embodiment, the reflective mirror surface **301** may be a highly polished silicon mirror or a dielectric coating. In alternative embodiments, it may be a reflective sheet or stripe.

FIGURE 3B is a perspective view of the exemplary area **350** illustrating an alternately adapted photodetector to receive light reflected from the interior surface of the cover **303**, in accordance with the alternate embodiment of **FIG. 3A**. As illustrated in **FIG. 3B**, the alternately adapted photodetector **320** has its window **331** facing the interior surface of the cover **303** in a coordinated manner to receive the cover reflected light **305**.

Alternatively, in one embodiment, the reflective mirror surface **301** may be disposed in such a manner as to reflect the second output **202** from the back facet **103** of the light source **101** to one or more other secondary reflective surfaces, such as, but not limited to, a side wall of housing (not shown). For these embodiments, the photodetector will be adapted accordingly in a coordinated manner to receive light reflected from the alternate secondary reflective wall by positioning the receiving window of the photodetector to face the alternate secondary reflective wall.

As a result, alternate interior surfaces of a housing of an optical transponder may be utilized to provide reflected light to a photodetector adapted to receive the reflected light.

Thus, it can be seen from the above descriptions, a novel method and apparatus for indirect monitoring of a light source by a photodetector, has been described.

The above description of illustrated embodiments of the invention, including what is described in the Abstract, is not intended to be exhaustive or to limit the invention to the precise forms disclosed. While specific embodiments of, and examples for, the invention are described herein for illustrative purposes, various 5 equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize. Thus, the description is to be regarded as illustrative instead of restrictive on the invention.

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